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Neal Hausmann
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INCORPORATING TECHNOLOGY INTO ANALYTICAL CHEMISTRY

by

Neal Hausmann

A thesis submitted in partial fulfillment of the requirements
for graduation with Honors in the Chemistry

_____

Laurie Croft and Claudio Margulis
Thesis Mentor

Spring 2018

All requirements for graduation with Honors in the
Chemistry have been completed.

_____

Johna Leddy and Ted Neal
Chemistry Honors Advisor

This honors thesis is available at Iowa Research Online: https://ir.uiowa.edu/honors_theses/162

Incorporating Technology into Analytical Chemistry

by

Neal Hausmann

A thesis submitted in partial fulfillment of the requirements

for graduation with Honors in Chemistry and Education

_____

Dr. Johna Leddy

Dr. Ted Neal

Honors Thesis Mentors

Spring 2018

All requirements for graduation with Honors in the

Chemistry and Education have been completed.

_____

Dr. Laurie Croft

Education Honors Advisor

Dr. Claudio Margulis

Chemistry Honors Advisor

Abstract:

This research project looks at how technology is being utilized in Analytical Chemistry 1 and how can technology usage be improved. The study started out with a lesson that was designed for discussion sections during one week of the semester. The lesson contained how to derive fractional concentration equations and how to use Excel to enter equations and plot the data correctly. After every discussion section was administered the lesson, every student taking the class was given a survey that asked questions about how it went and how is the class currently going. The survey also had an example problem so that I could compare how the students that went to the discussion did to the students that were not in attendance. The student's reviews for the most part had similarities. Most students thought that my lesson administered was very successful to their understanding of the material. Students want the discussions to be more valuable to them because majority of the class does not show up to the discussions because they find them not useful. Therefore, the discussion have to have some value for the students. The students that showed up to my discussion did better on the example problem than the students that did not show up. This shows that when Excel is practiced with the students they will do better on analytical plotting questions. So to combine what was learned from this study, the discussions should include problems that use Excel for practicing the functions. This will also make discussions more valuable which in turn will cause more students to attend.

Introduction:

I am a chemistry major at the University of Iowa and I took Analytical Chemistry 1 in the fall of 2016 with Professor Leddy. Students in this class must have a strong understanding of how Microsoft Excel works because this course cannot be taught using just pen and paper. The entirety of the second half of the semester includes deriving equations to be used on complicated

spreadsheets, to easily see patterns, and solve pressing questions based on what is happening in the beaker. Homework during the second half of the semester was entirely completed on Excel spreadsheets. Although the class was comprised of excellent students, and the majority struggled greatly to meet the deadlines for the assignments. Some struggles came with “simple” Excel functions and other struggles came with simply not knowing how to use Excel in the way the problem asked. Students attended office hours to get the homework done correctly and on time. I do not know how students would have been able to do well on the homework without going to office hours. This was reflected in the averages of the homework assignments.

The average grade for homework assignments, involving detailed Excel spreadsheets, hovered around 50 to 60 percent. Exams are meant to be and always should be harder than the homework because you have to finish an exam in one sitting. The second exam for the semester, when I took the course, was over all the homework that we used Excel for. The exam was held in a computer room and used a software called *LockDown*. This software allows the instructor to make sure students are locked into the Excel sheets, and cannot go outside of the Excel sheets to cheat. Because the exam was set-up like the completed homework assignments, student scores on the exam were similar to the overall homework averages.

Literature Review:

As I read through articles on analytical chemistry and undergraduates taking this course at colleges across America, I found many negative articles. One article stated that since the demand to learn analytical techniques, and there are many, this takes away wet chemistry and increases the amount of time for the material to be taught. There is apparently a lack of enthusiasm by undergraduates taking the analytical course (Hughes, 1993). Most college students in all of the chemistry courses I have taken show little enthusiasm while in class. Exams

and lectures are usually not something that students look forward to when attending college. At the University of Iowa, there is an Analytical chemistry course where the course just consists of lectures and later, there is a course, which I am currently enrolled in, called Synthesis and Measurement where we actually get to practice a few analytical techniques. This ensures that all the techniques can be covered in one semester, which is plenty of time, and students can spend part of a semester practicing those techniques in a lab setting. J.W. Robinson's take on analytical chemistry is a little different. He says that it appears that analytical chemistry is disappearing from the undergraduate curriculum. Analytical chemistry has a bad image because some of the techniques may not seem useful and have anything in common with organic or physical chemistry techniques. This is simply not true because analytical chemistry contains branches or every other type of chemistry. Analytical techniques are vital to the success of other types of chemist's research. "Organic chemists are teaching subjects such as gas chromatography, infrared, ultraviolet, nuclear magnetic resonance, etc. Physical chemists teach X-ray, nuclear science, statistics" (Robinson, 1968). These are taught in their prospective courses but also should be taught in an analytical course. Therefore, analytical chemistry is not vanishing from colleges but only becoming centralized into physical and organic methods. This is dangerous because students may not see the phenomenon that chemists use all these methods in different chemistry settings. Analytical chemists should be better at teaching chemical and physical techniques than other chemists due to the fact that analytical chemists are well balanced with many techniques. They are not focused on one piece of chemistry. Teaching analytical chemistry saves so much time in other divisions of chemistry because it can cover all the major techniques in the other branches of chemistry. So the other courses can briefly overview the material and get to the experiments. J.W. Robinson goes on to write about how professors might diverge from the

material to teach something that is comfortable to them. This is most likely material from their research (Robinson, 1968). As a senior this happens in every chemistry course and gives the students real life examples so this is not entirely a negative thought.

Since analytical chemistry at the University of Iowa is first taught in a lecture course there has to be a way to introduce technology. Analytical chemistry is a quantitative subject that utilizes Excel to set up graphs and data tables to easily see the patterns of what is actually happening. I do not even want to think of how analytical chemists survived without Excel existing during their time. Robert De Levie explains that Excel is very useful for many reasons. Excel makes changing data very easy and seeing the effects on graphs and tables simple (De Levie, 2001). Excel is also almost error free and the only difficulty that I have had with excel is making an error on my own and then having to try to find that error in all the data. De Levie, as well as myself, believe that Excel is very easy to learn even for beginners. Excel in an analytical course can bring what is happening inside the beaker come to life. For example titrations of polyprotic acids, which is what my exercise covers. Although Excel is easy to learn and very useful, there are still some students that have not used Excel in their lives and still need to learn how to use it properly. After reading these articles, I realize that I was lucky to take analytical chemistry at this university because it is offered to the students. This course has most definitely helped me Excel in chemistry.

Methodology:

Professor Leddy approached me at the end of the semester and asked if I would help her deliver analytical chemistry in a clearer way to her students. I was in the honors program at the University of Iowa already and was looking for a research opportunity. Professor Leddy teaches analytical chemistry only in the fall semester, so I had an entire spring semester and summer

break to decide to help. The research topic that I took on was how to teach analytical chemistry better than how it was delivered to myself when I took the class. The component that I was involved with was specifically how to use technology in analytical chemistry. Technology cannot be ignored in this classroom and some students have never dove deep into knowing Excel advanced functions. There are some engineers that take this course and some have not taken courses that teach you basic and advanced functions of Excel. While, some engineers are very familiar with Excel. So I wanted to focus on how to teach students Excel when some students are comfortable with it and others are not. I also wanted to get feedback from the students.

After returning from summer break with ideas, Professor Leddy and I bounced thoughts off of each other. The technology portion of the course does not take place until after the first exam so I would not be jumping in until then. We decided that I would create a lesson that teaches the critical Excel functions without teaching the functions directly. This meant I would create a lesson that would be like a homework problem and the students will have to complete that problem using Excel. So to correctly finish the problem the students will have to use Excel at the same time as learning how to complete the problem. I felt this was a good idea because the students that already know Excel can focus on how to solve the problem while I would be able to help students that do not know Excel functions. This lesson was to take place starting the week of October 9th 2017. To get feedback and data from this experiment, Professor Leddy and I thought it would be best to give the students some type of questionnaire after they attended their discussion. It was my responsibility to prepare questions to get the best data possible from the students. I created a survey with 5 questions including one question that asked students to complete an Excel sheet showing a complete 4-protic acid fractional concentration plot with its corresponding data. I also made a rubric for what I wanted this fractional concentration plot to

look like so I can compare the anonymous responses. We made the survey extra credit for the students, but it was a very small number of extra points and every students was able to take the survey even if they did not attend my discussion.

As my discussion week came closer I had concerns of possible issues that could go wrong and I will list them now and address them later. My first worry was if any students will show up to my discussion because when I took the course not many of my peers showed up to discussion. I worried if my exercise would be too hard or too easy for students to complete. I have never taught a lesson that had to last 50 minutes and never taught college level students, although I was confident in my lesson and my ability to teach the students. Also, I worried if no one would show up to my discussion or if students would even take part in my survey. Even though there was extra credit it was not enough to help a student's grade.

Professor Leddy and I came down to the conclusion that I was to make my own lesson on technology tied in with fractional concentrations. Fractional concentration plots clearly show the dominant and minor species in a solution. I then carried out this lesson one week of discussions. The different tabs for the lesson created shown in the appendix. The lesson consisted of an exercise first looking at a fractional concentration plot and having the students discuss with me what the major points are on that plot. I wanted the students to understand what the major points were before just plotting them and having no understanding of what is actually happening with the data. On the next tab, I had a simple monoprotic graphing example. I gave the students a pKa and all the necessary column headings so they can simply input the data. I wanted this portion to be mostly about the graphing aspect so students can have questions focusing on graphing. I included the equations necessary to fill in the columns hidden, so if a student was struggling on this they can see the correct answers. I do not like giving correct answers, but I thought it was

necessary here because further in the lesson students will have more struggles with deriving the formulas. I supplied the students with a blank line graph so the students only had to learn how to input the data correctly to create the right fractional plot. The next portion was creating a diprotic fractional concentration plot. This might sound similar to the previous plot, but a diprotic acid is capable of donating two protons (Hydrogen atoms) per molecule. This occurs when the molecule is dissociating in an aqueous solution. This problem is a little more difficult because there is a longer derivation of the alpha values as well as a denominator formula. For this I gave the students all the column headings, the two pKas, and the pH range. They had to derive and calculate the rest. At the time, I did not know if the exam covering this would be an online exam or a paper exam. This exercise covers both the online exam preparation and paper exam preparation. The semester I took the course we had an online exam. This year a paper exam was used to test the students understanding of the material. These equations for alpha values can be memorized if studied, so I had to make sure students were actually carrying out the derivations if the exam was on paper. If time permitted, I created a fourth and final exercise in this lesson. This was a more advanced problem for students who may have completed the other three exercises relatively quick. This educational technique is called differentiation. This exercise was to make a triprotic graph while only being given the 3 pKas. All derivation steps had to be shown. I did not give any column titles or graph type. The students had to basically start from scratch and use all the techniques the students should know about fractional concentration to create an appropriate plot. After the week, Professor Leddy allowed me to give a survey to the students to ask for improvements on the lesson and their thoughts. The survey also included a question that tested their knowledge on how to plot a fractional concentration plot. The question asked the students to make a quadprotic acid concentration plot while only being given the pKa values. Every

student had access to this survey even if they did not attend my discussion. This way I can compare how the students that went to discussion did compared to the students that did not attend the discussion. In short, I decided what the lesson and survey should be made up of.

Once the exercise was complete I worked on a rubric and started to go over the data which I will dive into soon. This was the only lesson I taught to the class the semester. My lesson was taught at the perfect time because the students were going to be asked similar questions on their next exam that was coming up. Overall, this research project turned out with positive results.

My project was the first of its kind for this class that I am aware of at The University of Iowa. As of now I completed the only research for this project. I hope this project can be carried on in further years by myself or someone new. Since this is the first, I wanted the project to start small. I hope that this project can grow into a bigger project because educating students should be held to one of the highest standards and always tested and challenged.

Data analysis:

This study gave valuable data during the lessons in discussion and valuable data from the responses and plots made in the survey. Only 11 students attended my discussion section for the entire week out of about 70 students in the entire class. This percentage of students showing up is not ideal, but this was anticipated for because, when I took the class, there were low percentages. I made the survey available for students who did not attend the discussion as well. A total of 28 students completed the extra credit survey and of those 28 students, 20 completed the fractional plot as well as the plot. To dive into the data, I want to go over what I observed while carrying out the lesson in discussion. Keep in mind, students have had practice with this material in this

course. On the first day, 6 people were at discussion, and all of them had laptops to work on the assignment because I told them to be prepared to have their laptops handy for the week's discussion sections. The lesson took all 50 minutes and two students were ahead of the class and were able to move onto the last two tabs to work on that while the rest of the students worked through the lesson. Most students needed help with creating a spreadsheet for my last tab on the exercise. Overall, I was happy with my first discussion because it went smoothly and I felt that every student left class having learned a new skill. I was disappointed that no students attended the second discussion at 8:30 am class. The final discussion went even better than the first. Five students showed up to this discussion. Each student asked questions throughout the discussion but not just on the graphing. They were confused with the deviations as well as the graphing. They were able to answer their own questions after I lead them in the right direction. I do not like giving answers because then students do not actually understand the knowledge. The only clear negative to the discussions was the lack of attendance. I feel that I could have done much more if more students attended, and if the discussions were done right before the homework was due instead of after. Complaints like this show up in the survey questions, as well as praise.

The first two questions in the survey coincide. The first question asked if you went to your discussion section for my lesson, and was the exercise helpful and how was it helpful? All ten students that attended my lesson said yes it was helpful but their reasons why are important. One student stated, "Yes. It clears off all the ambiguities I had on the fractional concentration plot. I hope there would be more of these discussions." This is the exact answer I was hoping for because these discussion should be used to clear up confusion in a smaller setting than a lecture. A few students answered saying this gave them more experience with fractional plots which helped them on homework, and they were also happy they were able to ask questions about

making their plots. Having an environment where students can ask questions is important when teaching and putting time for questions in a lesson. There was one response that made me cringe a little because that was the opposite of what I wanted to occur. That response was “It really helped cement the alpha equations in my head.” Even though this was the only response like this, I am still bothered my lesson allowed this to happen. I did not want students going through my lesson memorizing the equations. I might have missed this student copying the equations from their notes and entering them into their spreadsheets. This is a negative, because again, the exam was written which means a student must show their work and not come up with the derivations from their memory. Another positive was a student claiming my lesson allowed him or her to, “Know the equation of the fractional concentration and how the graph relates to the data.” This is fantastic because the lesson taught the concepts of fractional concentration plots, not just the content. Teaching the concepts is critical because a student can fully understand the concept and relate it to other scenarios. My final positive feedback from my lesson highlighted my teaching and lesson when this student said, “It really helped clarify how to use Excel.” It was also taught by someone who had taken this class so he understands the worry we might have or confusion. I thought the Excel sheet he set up was done nicely and easy to use. It was also helpful because he walked around and answered and any questions we had, individually. So he actually saw our computer screen and the issue at hand.” This response had many positive parts. First positive, was my lesson clarified how to use some Excel functions which I helped a few students struggling with these issues. Also the templates made for the students to work on had no issues and did not limit or lead the students to the right answers. Finally, even though it is all about the students coming to understand the material, it was nice to see another positive response on my teaching because this was my first time ever teaching a lesson I have created.

The next question asked was “Are there any improvements that can be made to the discussion exercise this past week?” This question is very important because this illustrates changes to improve in this course. I want to go through the constructive criticism first because it can turn into positives when fixed in the future for this course. One complaint was a student wishing the lesson was done earlier because there were a couple homework problems that my lesson could have covered and helped students to complete the assignment. A quick fix for this is for me to understand what will be on their upcoming homework assignments. The best criticism came from a student that did not attend my discussion. The student said, “I think we spend too much time doing stuff that isn’t as applicable or what students are struggling with. I imagine this is why other people don’t go to discussion as it hasn’t been helpful recently and it is more beneficial for me to use that time to practice these problems on my own or with friends.” This response highlights making discussion sections more pertinent to student’s needs. I feel there should be lessons like mine every week before a homework assignment because the homework in this course is difficult at times, and students will want to come to discussion and learn. Another student thought more exercises would be a good addition. This lesson took the entire class, but I could have added some problems at the end of my Excel document for the students to do on their own. This could also give more differentiation in my lesson as well for more advanced students in the material. The rest of the responses were positives on the lesson. One student wanted me to teach at least another lesson to them by the end of the semester.

The next question that was asked of the students was, “Should technology be utilized in discussion to help with difficulties in using Excel to solve problems? Why?” I felt that this question was important because all students who completed the survey can answer this question. There were 20 responses that said yes and one that said no with no explanation. Technology

should definitely be used in discussion to help with issues. If I remember correctly, I do not think we went over the basics of Excel and how to use Excel with fractional plots in discussions when I took the course. Most of the yes answers said something along the lines of not having enough experience or needing a refresher course on Excel. One student made a good point about how he or she is an engineering major and is heavily exposed to Excel, sand they do not need a refresher exercise. But this student did not attend my lesson where there was differentiation for student's to work on more advanced problems, if needed. There was not much difference between answers here. All these answers show the importance of having lessons that use technology for this course.

The final part of the survey was for the students to upload an Excel sheet showing a 4-protic fractional concentration plot. They needed to include pH, H+, alpha, and check sum calculations as well as the concentration plot. Every student was allowed access to this so I could compare how students that showed up to my discussion did to those that did not show up to my discussion. A total of 24 Excel sheets were uploaded and of those 24, 9 who came to my discussion uploaded a spreadsheet. I created a rubric that I felt covered all of the necessary material that was useful to measure. The highest score achievable was 24 points. The average score of the students spreadsheets that showed up to my discussion was a 20.8 out of 24 points. The average score of students that did not show up to my discussion was 19.7 points out of 24 points. The average was brought down for students that attended my discussion because one of the students did not include a graph, therefore they brought down the average because they probably forgot to put one or just lazily submitted the assignment. This student's spreadsheet had the correct values and correct equations. This student knew the material. Even with this blemish, the students that came to my discussion did one point better than students that did not show up. I

calculated the standard deviation from both groups, leaving out the student that scored a 9 out of 24, because this student does not show if they actually know the material. The standard deviation between the groups of students that came to my discussion is lower than the standard deviation of students that did not come to my lecture. This shows that the students that showed up to my discussion all ranged around the mean score and there were not many high scores and many low scores. All of the scores were very close to one another. However, for the group that did not show up had many scores that were well below the average and many scores that were well above the average. This shows that students that did not show up to discussion either knew the material and did not need to show up, or did not know the material and still did not show up.

Now for the interesting part, connecting how the students did on the Excel sheet to what their response was to the question "should technology be utilized in discussions to help with difficulties." First, let's start with students that did not show up to discussion. One student that scored a 22 out of 24 on his or her Excel sheet had a simple response of "No" to the question. This student had a simple mistake with numbering which is not a big issue. Therefore, to not waste this student's time in discussion, the discussion must have some sort of differentiation so students that Excel can work on more challenging problems to further their understanding. Another student that scored high and did not show up for the discussion commented that they were an engineering student. They also commented that even though they knew the material, this lesson helped a lot with understanding the components of Excel and plotting. There is a common trend of students doing well on the plot and not showing up because it is a waste of their time. Therefore, this discussion cannot be a waste of time and to do that there must be more difficult material for these students to work on.

The next type of student's responses to review are those that did not show up to discussion and did poorly on the plot. Two students that did poorly on their plot had interesting responses to the question. The first student said, "Yes because some problems take too long!" This student received a 12 out of 24 and clearly did not know how to use Excel because they did not know how to select data and make a fractional concentration plot. They also did not seem to understand the material because they were missing alpha values. This shows that technology must be introduced in discussions which will also clear up the material as well, because they go hand and hand. The next student said, "Yes, the more examples we can walk through the better." Not many examples were shown in lecture due to time restraints which is why there are discussions to go over material with more exercises. All of the errors that they made would have been cleared up in my lesson and his or her score would not have been low.

Now, time to review the response of students that showed up to discussion related to their score. The student that scored the 9 out of 24 said that showing technology in discussion "helps a lot." Since my lesson covered graphing and the survey clearly states to graph, I conclude that they simply forgot to include a graph. All of the student's responses in this category were yes except for one. The student that replied no received a 24 out of 24 on their Excel sheet. Therefore, I was glad that my lesson contained a differentiation activity to not waste this student's time. This student coming to my discussion is important because I do not want this course to have discussion for only students struggling. I feel that discussion should be for every student, and every student can improve on all material. There are always students that will show up to discussion that are excelling in the course and time is wasted because the discussion does not have activities that challenge them. Every discussion has to have exercises prepared in advance to insure that students are learning.

Discussion:

This research project has many findings. The first finding is that not enough students show up to their discussions. Even students that are struggling with material do not show up which is shown in the averages listed in the appendix. To get students to show up to the discussions there must be challenging exercises and lessons. They should be challenging to push the students' knowledge further or else students will find it useless. The lessons should include material that will help them understand the coursework both on homework and exams. Also, the discussions must include how to use Excel to enter data and make plots. The students clearly state this from their responses. Excel's functions should be introduced in discussions before the material for the course becomes dependent on Excel. The discussions must not waste student's time that already Excel in the material so there must be some sort of exercise that challenges these students. This research project can be carried out in the future. The great aspect is that research can be done on any chemistry course here at the University of Iowa. Although, the projects would have to be tailored a little differently than mine due to what the professor wants the focus to be on their course. This also allows courses discussions or lectures to be held accountable to some standard because the student will look for improvements and what part of the instruction is failing. In my time at The University of Iowa, the courses that I exceled in the most were the courses that had very well taught discussion sections. Discussion sections are where students can ask questions, work on exercises/homework, and prepare for exams. Discussions are very important for student understanding, and should be taken seriously when planning science curriculum in science courses here at The University of Iowa.

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Appendix

Lesson Excel Tabs

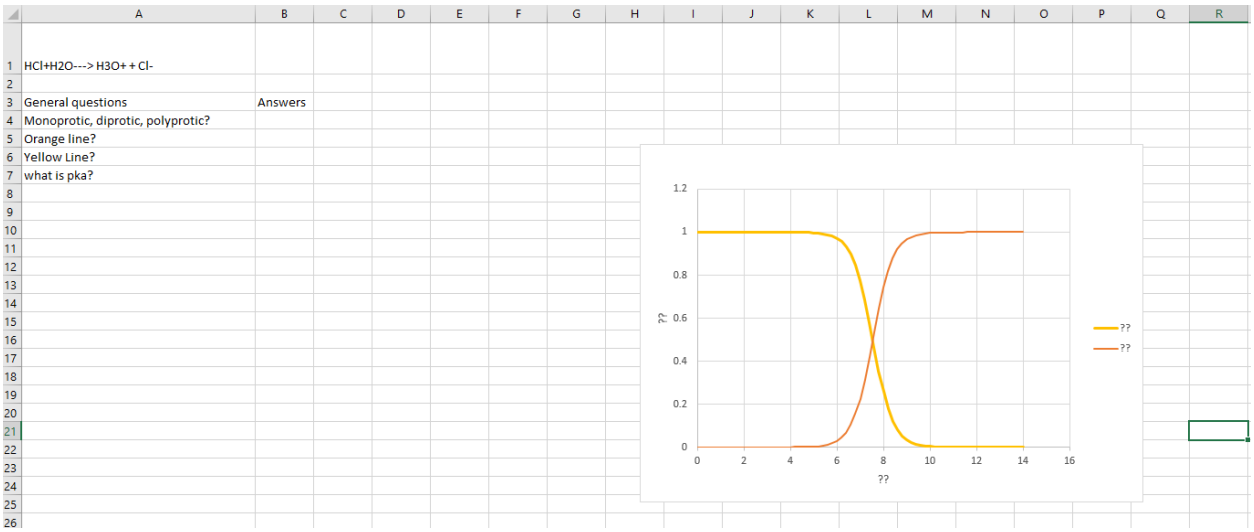


Figure one: First exercise carried out in the lesson**.**

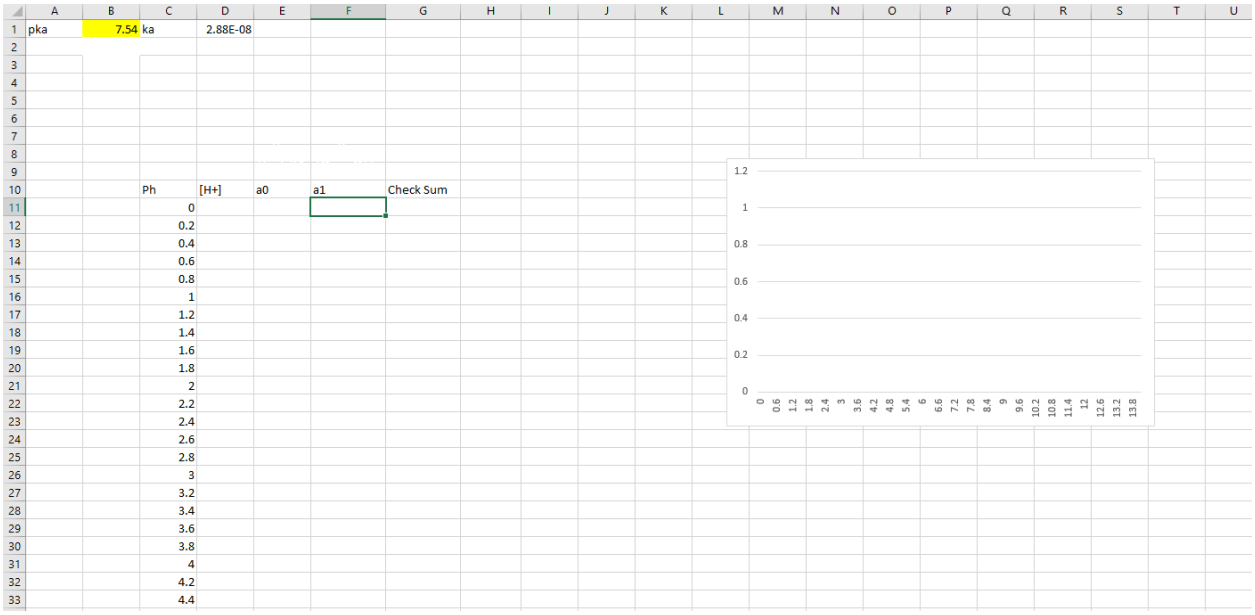
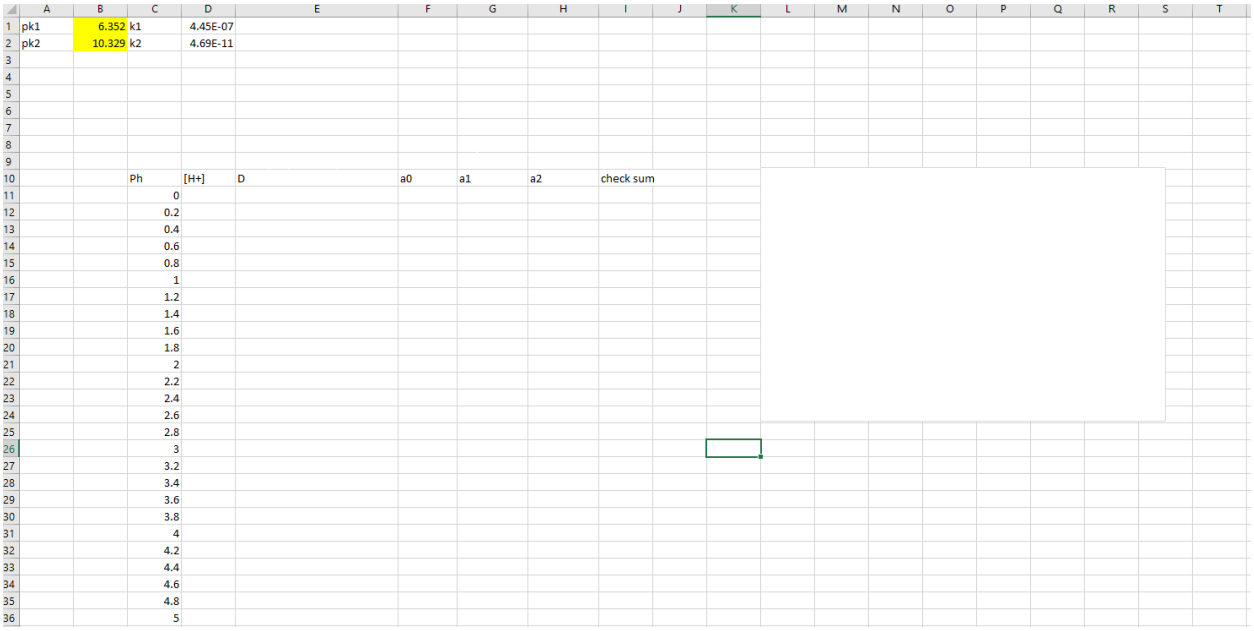
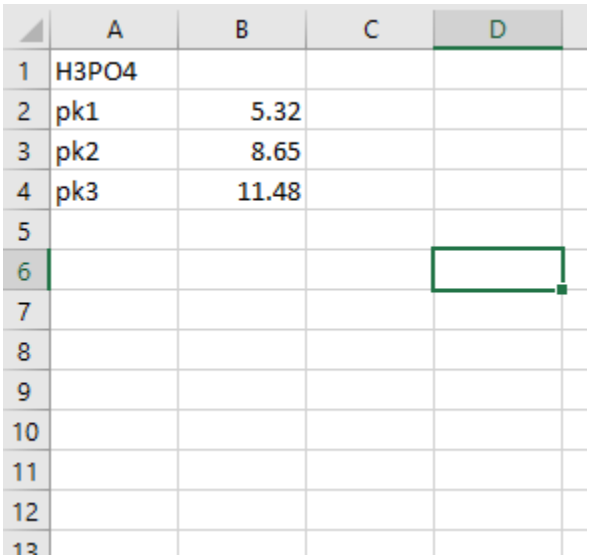


Figure two: Second exercise in the lesson



	A	B	C	D	E	F	G	H	I	J	K	L	M	N	O	P	Q	R	S	T
1	pk1	6.352	k1	4.45E-07																
2	pk2	10.329	k2	4.69E-11																
3																				
4																				
5																				
6																				
7																				
8																				
9																				
10			Ph	[H+]	D		a0	a1	a2	check sum										
11			0																	
12			0.2																	
13			0.4																	
14			0.6																	
15			0.8																	
16			1																	
17			1.2																	
18			1.4																	
19			1.6																	
20			1.8																	
21			2																	
22			2.2																	
23			2.4																	
24			2.6																	
25			2.8																	
26			3																	
27			3.2																	
28			3.4																	
29			3.6																	
30			3.8																	
31			4																	
32			4.2																	
33			4.4																	
34			4.6																	
35			4.8																	
36			5																	

Figure 3: Third exercise in the lesson



	A	B	C	D
1	H3PO4			
2	pk1	5.32		
3	pk2	8.65		
4	pk3	11.48		
5				
6				
7				
8				
9				
10				
11				
12				
13				

Figure 4: Final exercise in the lesson. Students had to create their own plot from this data.

Discussion participation

10 people went to discussion

28 people attempted the survey

8 people did not fill out plot for survey

Student responses to survey questions (Z denotes this student did not make a fractional concentration plot)

If you went to your discussion was the exercise helpful? How was it helpful?

- yes very helpful **(student E)**
- Yes. It clears off all the ambiguities I had on the fractional concentration plot. I hope there would be more of these discussions if we had to learn to plot something. **(Student G)**
- Yes. It helps me to know the equation of the fractional concentration and how the graph relates to the data. (**Student H**)
- I didn't go to discussion but I went to class and found it very helpful. (**Student K)**
- Yes, it was very helpful. It really helped clarify how to use excel. It was also taught by someone who had taken this class so he understands the worry we might have or confusion. I thought the excel sheet he set up was done nicely and easy to use. It was also helpful because he walked around and answered and any questions we had, individually. So he actually saw our computer screen and the issue at hand. (**Student M)**
- I know how to select data and create a plot that the data X and Y axis are what I want to present. I think it is very helpful, because I was so stressed out when I can't put the correct Y or X axis when I doing the excel. (**student Q)**
- It really helped cement the alpha equations in my head. (**Student R**)
- It was very helpful for the most recent homework assignment. I felt very prepared and knew exactly how to go about making all the fractional concentrations plots (and there were LOTS of fractional concentration plots) (**Student S)**
- The exercise was helpful. Â It gave more experience and a time to ask for help with solving problems related to fractional concentration plots (**Student T)**
- Better understanding what we learn in class (**Student U)**
- Yes, it was helpful. Because through exercise, I have a deeper understanding of making fractional concentration plot and through the plot, I can easily know each concentration in different pH. (**Student V)**

Are there any improvements that can be made to the discussion exercise this past week?

- I thought I learned a lot more exercises would be nice **(Student E)**
- No. It was very helpful to me, perhaps getting a few handouts would help, but the excel document on ICON did the job anyway**. (Student G)**
- The skills of using excel. (data analysis and plot) (**Student O)**
- I think we spend too much time doing stuff that isnt as applicable or what students are struggling with. I imagine this is why other people dont go to discussion as it hasnt been helpful recently and it is more beneficial for me to go use that time to practice these problems on my own or with friends. (**Student K)**

- I think we could include how to do a titration curve. Neal is a good (college student) instructor, so I think it would be awesome if he could come in again and teach us how to do a titration curve. But also Sanjaya could lead them too if we go slowly and loudly through each step. I like the set up of starting off easy, then as we add a proton one aide on the excel sheet is taken away until we have to do it all on our own. (**Student M)**
- I think this is discussion is very helpful. I learned a lot. Thank you! (**student Q)**
- My only comment was that I wish we would've done the exercise earlier, because by the time of discussion we had already done some of these problems for the homework, and it would've been nice to have more background before that homework was due. (**Student S**)
- Although it may not be possible for this specific exercise, it may help to let the students find the equations in their notes instead of plugging them into Excel. Â After letting the students work on the problem for a bit, then go through the equations for those who didn't find the equations in their notes and solve the problem. (**Student T)**
- I think everything is fine and people who do presentation do a really good job. (**Student V)**

: Should technology be utilized in discussion to help with difficulties in using excel to solve problems? Why?

- As a chemical engineering major, the engineering curriculum has heavily exposed me and my classmates to excel prior to this course. Â However, I am unsure if other majors get that kind of exposure early in their studies. Â Fractional concentration plot generation is a great way to practice some very useful skills in excel, including Plot generation and formatting, use of formulas, formula short cuts, data type manipulation, etc. Â I would suggest continuing to give the students this exposure. (**Student A)**
- In my opinion, discussion sections should include detailed demonstrations of formatting an excel spreadsheet to do calculations that are either too complex or lengthy to do by hand. I think this would be beneficial to students, because most classes neither require nor cover the use of excel, and many of the calculations done in the homework are much easier when done in a spreadsheet. (**Student z1)**
- yes, excel should be used in discussion to help with difficulties in using excel to solve problems. (**Student B)**
- Of course. Since the difficulties that need to be addressed are excel related, and excel is a software based on computer technology. I don't think these difficulties can be addressed without using technology. (**Student C)**
- Yes, don't have to figure out how to do excel on your own. (Student D)
- yes it would make it more helpful (**Student E)**
- Yes, often times I have troubling inputting equations and fixing errors because of lack in excel experience **(Student z3)**

- Yes! Excel is a very beautiful but difficult program and a crash course would be very useful. (**Student F)**
- No. . But yes, when it comes to plotting exercises like this. It is like practical training in certain jobs. (**student G)**
- Yes. Many questions need to use excel to analyze data. The technology utilized in discussion helps me to use excel better. It is helpful for me to solve the problem of fractional concentration. (**Student H**)
- Yes because some problems take too long! (**Student J)**
- I think using the class time to learn how excel can be applied to do our homework was very helpful as it saved A LOT of time by knowing exactly what I needed to do. I believe that setting up so many excel sheets has also solidified the concepts behind fractional concentration plots. (**Student K)**
- Yes, the more examples we can walk through the better. (**Student L)**
- Yes!! I do not have a good understanding of how to use technology, and I understand that sometimes it is not possible to do it during class; however, I would REALLY appreciate it if we could confidently talk over it in discussion because not everyone has taken basic measurements. A lot of this material is done on the computer & excel, so in order to work efficiently in class & understand the material we need to have a strong base. I think if we don't have our technology during discussion and we have issues with excel, then the TA explaining his answer just verbally with no demonstration nor the ability to apply his solution to your excel sheet right then and there will not be helpful because it could turn out that the TA's solution still doesn't work/help. But you won't know until you are alone trying it, and then you are out of ways to ask help because it would be hard to maybe explain over email. Also then the TA could demonstrate efficiently his step-by-step way to work through excel and apply his solution. If it doesn't work there then we can try and problem solve a new solution with the TA present.Â (**Student M)**
- Yes (**Student N)**
- Learn how to solve problem in different ways is also a part of discussion. (**Student P)**
- I think we should consider that when we have trouble to do the excel, because we can better understand the class topic, material, and we may using those skills in other courses or areas. **(Student Q)**
- It deffinetly helps a lot, but it is not nessesary if we can bring it to office hours. (**Student R)**
- YES! It is really difficult to figure out excel all on your own, and the internet is really limited in information for the type of problems we cover. It would be awesome if we could spend more time doing excel problems in class. (**Student S)**
- Yes because there can be helpful tutorials used for formulas used inside the individual cells. (**Student z7)**

- I think that some of the time, Excel should be used to solve problems. It would give the necessary experience needed to complete homework sets since some problems should be done in Excel. Â It would also give students experience plugging equations into Excel and asking for help if something goes wrong during the process. Â However, I think that some of the time there should be problems worked out by hand since exams are completed on paper and not in Excel files. Â (**Student T)**
- YES (**Student U)**
- Yes, because of some question, it is not easy to get the answer only by the calculator, if we use Excel, the question would be easier to be solved. And just type the equation on the excel to get the answer is convenience way. Â (**Student V)**

Rubric for grading excel plots

CATEGORY	4	3	2	1
Units	All units are described (in a key or with labels) and are appropriately sized for the data set.	Most units are described (in a key or with labels) and are appropriately sized for the data set.	All units are described (in a key or with labels) but are not appropriately sized for the data set.	Units are neither described NOR appropriately sized for the data set.
Data Table	Data in the table is well organized, accurate, and easy to read with correct equations	Data in the table is organized, accurate, and easy to read with a few mistakes with equations	Data in the table is accurate and easy to read with many mistakes with the equations	Data in the table is not accurate and/or cannot be read.
Neatness and Attractiveness	Exceptionally well designed, neat, and attractive. Colors that go well together are used to make the graph more readable. A ruler and graph paper (or graphing computer program) are used.	Neat and relatively attractive. A ruler and graph paper (or graphing computer program) are used to make the graph more readable.	Lines are neatly drawn but the graph appears quite plain.	Appears messy and \"thrown together\" in a hurry. Lines are visibly crooked.
Accuracy of Plot	All points are plotted correctly and are easy to see. A ruler is used to neatly connect the points or make the bars, if not using a computerized graphing program.	All points are plotted correctly and are easy to see.	All points are plotted correctly.	Points are not plotted correctly OR extra points were included.
Title	Title is creative and clearly relates to the problem being graphed (includes dependent and independent variable). It is printed at the top of the graph.	Title clearly relates to the problem being graphed (includes dependent and independent variable) and is printed at the top of the graph.	A title is present at the top of the graph.	A title is not present.
Type of Graph Chosen	Graph fits the data well and makes it easy to interpret.	Graph is adequate and does not distort the data, but interpretation of the data is somewhat difficult.	Graph distorts the data somewhat and interpretation of the data is somewhat difficult.	Graph seriously distorts the data making interpretation almost impossible.

Scores

Students, Attended discussion (y/n)

A-24, n

B-21, n

C-21, n

D-19, n

E-18, y

F-20, n

G-24, y

H-21, y

J-12, n

K-24, n

L-17, n

M-24, y

N-22, n

P-16, n

Q-24, y

R-9, y

S-19, y

T-24, y

U-21, n

V-24, y

showed up	not showed up
24	24
21	21
24	21
24	19

9		20
19		12
24		24
24		17
18		22
		16
		21
20.	Average	19.7
2.5	Std	3.5